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ABSTRACT

This study compared the effects of computer and print text density on learning using 48 undergraduate teacher education majors as subjects. Three separate studies tested the effects of text density and presentation modes (print or computer), learner control, and screen density. Dependent variables for the first two studies--which were related--were differing types of learner achievement (knowledge, calculation, and transfer), lesson completion time, and learning efficiency. The study on screen density measured student preference. The data showed that low-density text was read faster and perceived as more sufficient than the same text presented in a print format. It was also found that when text density was used as a decision variable, learner control groups learned better than groups receiving standard materials. The results indicated that the less skilled readers typically selected high-density text while the skilled reader selected low-density text. Thus, it is suggested that text density could be used as an adaptive strategy with appropriate changes in text density throughout the lesson. The text is supplemented by three figures. (42 references) (EW)

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Research in Computer-Based Instruction

Screen Density and Text Density: Getting More Out of Less with CBI

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Although the computer screen and printed page are both used to present text, there are unique qualities and constraints the designer must consider when working with each (Hartley, 1987). A review of commercial software packages will reveal that the computer screen is frequently treated as an electronic representation of the printed page (Bork, 1987; Burke, 1981; Keller, 1987) with the designer attempting to follow the same rules and heuristics that have guided both the design and layout of printed information. Comparisons between microtext and print on difficulty and reading speed have yielded mixed results (Barbe & Milone, 1984; Fish & Feldmann, 1987; Hansen, Doring, & Whitlock, 1978; Heppner, Anderson, Farstrup, & Weiderman, 1985; Morrison, Ross, & O'Dell, in press; Muter, Latremouille, & Treurniet, 1982), but an apparent limitation of many of these studies is the failure to design the text displays in a manner that fits each medium. Fish and Feldman (1987) for example, made their print pages duplications of their computer-based instruction (CBI) screens, a procedure that adds rigor to the comparison, but little realism.

Constraints imposed by the computer display include (a) a display limited to one page at a time, (b) restricted backward paging and review, (c) page layouts in either 40 or 80 columns by 24 lines, (d) limited cues as to lesson length, and (e) relatively poor resolution. Advantages of the computer include the ability to create response-sensitive, highly flexible, and dynamic displays without cost constraints on the use of color or number of pages. Recent suggestions for the design of computer displays emphasize minimizing the amount of text presented by using wide margins, double-spacing, and fade-out of unneeded information (Allessi & Trollip, 1985; Bork, 1987; Grabinger, 1983). Implementation of these guidelines, however, has the disadvantage of requiring an increased number of frames to display the same amount of information. It seems both theoretically and practically important to explore ways of using screen display areas efficiently.

The research described in this paper was designed to identify alternative methods for displaying computer text. Its specific focus was on the level of "richness" or detail presented in each display, a variable that we have labeled "density level." In related research with print material, Reder and Anderson (1980; 1982) compared complete chapters from college textbooks to summaries of the main points on both direct and indirect learning. The summaries were found comparable or superior in 10 studies reported. They concluded that the summaries may help the learner focus on the main ideas without the distraction of additional elaborations.

Similar to Reder and Anderson's (1980; 1982) construct, the present text density variable includes such attributes as length of material (number of words), redundancy of ideas, and depth of conceptual support for the main ideas. Reading researchers have referred to such text attributes as "microstructure" (Davidson & Kantor, 1982). Following Reder and Anderson's, procedure we generated low-density material from conventional text by: (a) defining a set of rules for shortening the text, (b) having two individuals apply the rules to the rewriting of the

text, and (c) requiring those individuals to arrive at a consensus on the content of the summary. The specific guidelines for shortening the text were as follows:

1. Reduce the sentences to their main ideas.
   a. Remove any unnecessary modifiers, articles or phrases.
   b. Split complex sentences into single phrases.
2. Use an outline form instead of a paragraph form where appropriate.
3. Delete sentences that summarize or amplify without presenting new information.
4. Present information in "frames" containing limited amounts of new information, as in programmed instruction.

Applying these rules to a textbook unit of instruction consisting 2,123 words on 18 pages yielded a final low-density version consisting of 1,189 words, a 56% savings on 15 pages, a 17% savings. In designing the final lessons, a critical decision was whether to match print pages to CBI screens in order to maximize their similarities for analyzing media differences. We decided instead to sacrifice internal validity to create highly realistic page and screen designs for evaluating text density effects (with high external validity) within each medium. Accordingly, print pages and computer frames were designed using what were subjectively determined to be the most appropriate layouts for the content. Final versions of the CBI lessons resulted in 49 frames in the low-density lesson and 66 frames in the high-density lesson. Figure 1 shows a sample frame from the two density levels. Both frames present the same main ideas, however, the high-density version includes additional elaborations and supporting context.

Insert Figure 1 about here

Our main research interest was testing the effectiveness of the low-density materials just described. Low-density narrative was hypothesized to promote better learning and more favorable attitudes on CBI lessons by reducing reading and cognitive processing demands of the screen displays. A second area of interest was the effect of learner preferences for the two density levels in the print and CBI modes. Prior research on learner control (LC) has shown positive results in some studies (Judd, Bunderson, & Bessent, 1970), while more recent findings have been negative (Carrier, Davidson, & Williams, 1985; Fisher, Blackwell, Garcia, & Greene, 1975; Ross & Rakow, 1981; Tennyson, 1980). In contrast to typical uses of learner control for selecting the quantity or difficulty of materials, the text density variable represents a "contextual" lesson property that would seem primarily oriented in subject-matter to accommodating differences in reading ability and learning styles (rather than aptitudes or abilities). Thus, it appeared worthwhile to explore as a learner control option. To investigate these questions, we conducted an initial study (Morrison et al, in press), which is summarized below.

Study I

Subjects were 48 undergraduate teacher education majors who were randomly assigned to six treatment groups. The treatment groups were arranged by crossing two presentation modes (computer vs. print) by three text density conditions (high, low, and learner control). Dependent variables were different types of learning achievement (knowledge, calculation, and transfer), lesson completion time, and learning efficiency. During a regular class meeting, subjects completed a brief survey to asses attitudes towards mathematics and CBI. They then attended small-group sessions in which they completed the instructional unit followed by an attitude survey and an achievement posttest.

Results indicated the high-density and low-density materials were selected almost equally by the combined CBI- and print-LC groups (n=16). The print group selected low-density text an average of 3.75 (out of 5) times while the CBI group selected high-density an average of 3.75 times, the exact opposite pattern. Achievement results indicated the print group performed significantly better on the knowledge subtest (definitions) and on the calculation subtest. No significant density level effects occurred. Print subjects (M=18.0 min.) took significantly less time to complete the lesson than did CBI subjects (M=32.3 min.), and the low-density group (M=20.8 min.) took less time than the high-density group (M=27.8 min.). With regard to attitudes, high-density print subjects perceived the lesson as moving faster than did CBI subjects. Also, low-density CBI subjects rated the materials higher in sufficiency than did the print subjects.

These results were consistent with those obtained for college textbooks (Reder and Anderson, 1980; 1982) by indicating that low-density materials were just as effective for learning as high-density materials. Also of interest was the LC density selection pattern showing the print group to prefer low-density material and the CBI group to prefer high-density material. This pattern, along with the very slow pacing by the CBI group, might indicate a lack of confidence by the latter in using the computer to learn. The results of the attitude survey indicated differences in the way the media and density levels were perceived. Print subjects judged the high-density material as moving faster than did the CBI subjects. This perception may have been due, in part, to the difference in the number of words viewed at a time (e.g., page density) in the two different modes. That is, with the realistic display formats used, CBI subjects were required to view almost four times as many "pages" as were print subjects. Another significant difference was that the CBI subjects rated low-density material as more sufficient than did print subjects. Thus, while high- and low-density materials had comparable influences on learning, "less" was perceived as "more" in the CBI mode.

A major limitation of this study was the low n (only 8 per cell) which obviously reduced the sensitivity of the various hypothesis tests. Other limitations were the lack of a pretest for evaluating the initial knowledge of the groups and a delayed posttest to assess long-term

achievement. The results also raise some interesting questions regarding the effectiveness of the LC strategy. Overall, and in contrast to the pattern in other studies (Hannafin, 1984), low-performers did not seem to favor the "low-support" option (i.e., low-density) text over higher support. High-density text was actually the predominant choice in the CBI condition in which achievement scores were lowest. Further, although no significant differences were found, learner-control was directionally highest for print subjects and second highest (below low-density) for CBI subjects on all achievement subtests. These results suggested a further examination of the learner-control strategy using a larger n.

Study II

Study II (Ross, Morrison, O'Dell, 1987) extended Study I in several ways. First, comparisons between density and presentation modes were replicated with larger samples, an immediate achievement posttest, and a delayed achievement posttest. Second, the examination of learner control was extended to include selections of both text density ("partial-LC") and presentation mode ("full-LC"). Specifically, as in Study I the partial-LC treatment allowed subjects to select either a high-density or a low-density presentation in the print and CBI modes. Subjects in full-LC treatment, however, were allowed to first select either the print or CBI mode, and to then select a high-density or low-density presentation within the selected mode. A third major interest was examining the relationship of individual difference variables of reading ability and prior achievement to learning from "conventional" (high-density) computer text displays.

Subjects were 221 undergraduate teacher education students. They were randomly assigned to the seven treatment groups arranged according to a 2(presentation mode: computer or print) x 3(density: high, low, or LC) factorial design with one outside condition (full-LC). Seventy-five subjects from the total pool were preassigned to the high-density CBI treatment to support the supplemental analysis of individual differences and learning in that treatment. Prior to the instructional session, subjects completed a preattitude survey, pretest on the instructional unit, and the Nelson-Denny Reading Test (Brown, 1976). During the instructional session, they completed the unit on central tendency used in Study I, the attitude survey, and the achievement posttest. A delayed posttest was administered approximately two weeks later.

Comparisons of the full- vs. partial-LC conditions found no significant differences due to LC-strategies on achievement, attitudes, density selections. There was, however, a significant interaction on completion time between LC-strategy and presentation medium. Under CBI, the full-LC group (M=18.9 min.) took significantly less time than the partial-LC group (M=29.0 min.), indicating that those who selected CBI completed the lesson more quickly than those who were prescribed CBI. In the full-LC treatment, subjects' choice of mode was almost equally divided between print (n=11) and CBI (n=13). A discriminant analysis identified reading rate to be a significant discriminator between those

who selected CBI and those who selected print. Subjects selecting CBI had a higher reading rate than those who selected print. Analysis of the number of low-density selections made by all LC subjects showed a general tendency for subjects to select low-density text (on about 70 percent of the trials) regardless of presentation mode. In multiple regression analysis, reading rate again was found to be the only significant predictor. As reading skills decreased, the tendency to select low-density material also decreased.

Significant density effects on achievement occurred on the calculation, transfer, and delayed retention measures. In all cases, the LC group had the highest mean of the three treatments with a significant advantage indicated on the latter two measures. The presentation mode variable in contrast, had generally small effects, only one of one of which was significant: CBI surpassed print on the delayed posttest.

Analysis of completion times indicated that the CBI group ($\underline{M}$=25.8 min.) took significantly more time than the print group ($\underline{M}$=21.5 min.), and the high-density group ($\underline{M}$=26.5 min) took significantly more time than the low-density group ($\underline{M}$=21.0 min). When the means for the CBI mode were adjusted to account for delays due to keypressing and screen construction, the presentation mode effect was no longer significant; however, the significant density condition was maintained.

The relationship between learner characteristics and learning from high-density CBI was analyzed using a stepwise multiple regression. When immediate posttest scores were treated as the criterion, reading comprehension was the first predictor entered in the equation with pretest score entered on the second step. No other predictors were entered. In contrast, reading scores were not selected as predictors in any other treatment group equations, while pretest was a consistently strong predictor in each.

The lack of difference between density levels is consistent with the results of Study I and of Anderson and Reder's (1980; 1982) research. An advantage of the low-density text was the significant reduction in lesson time without an associated reduction in learning. Results of the LC comparisons further suggested that learners are capable of making appropriate decisions when selecting contextual lesson attributes such as presentation mode or text density level. This finding is in contrast to negative results from LC applications which required learners to select the sequence, difficulty, or the amount of instructional support they needed to achieve objectives (Hannafin, 1984). Accordingly more skilled readers tended to select low-density text while less skilled readers tended to select high-density text, seemingly desirable strategies for both groups. This pattern coupled with the tendency to vary selections across lessons, suggests that the subjects attempted to adapt instructional demands to match specific needs as learning occurred.

Study III

A confounding variable in the CBI density comparisons of Studies I and II was screen density, the proportion of the display area containing characters as opposed to white space. Specifically, the frame structures into which the high- and low-density lessons were logically organized naturally resulted in sparser screens with the latter (low-density) material. Were the reactions to the density variations by LC-subjects primarily determined by the reduced content (text density) or by the less cluttered screens (screen density)?. As a first step toward answering this question, Study III was designed to examine what screen density levels for displaying textual material are most appealing to learners.

Prior research in the area of human factors engineering has produced several recommendations on this issue. Screen density is the amount of the screen actually used to display text or graphics, for example, a 40-column by 24-row screen can display a maximum of 960 characters. Danchak (1976) recommends a maximum screen density of 25% while most screens judged as "good" had a density of 15%. NASA (1980) recommends that screen density not exceed 60%. Smith (1980; 1981; 1982) recommends a maximum screen density of 31.2% and a minimum of 15.6% for 80 column screens.

Using these recommendations as a guide, we designed a study to determine which density level was most preferred by our learners. A possible limitation in typical studies of screen density preferences is the procedure of having subjects react to isolated, individual screens represented in the different density gradients. In cases, such as Grabinger's (1983) study, symbolic notation (Twyman, 1981) rather than approximations to English (c.f. Morrison, 1986), or actual lesson content comprises the "text." Would format preferences be the same with realistic content than with artificial prototypes? More specifically, in actual lessons, creating sparcer displays will necessarily require a greater number of screens. Does low-screen density seem as attractive to the student considering that tradeoff?

Subjects in this preliminary experiment were 35 education majors consisting of 14 undergraduates and 21 graduate students, and 26 females and 9 males. The stimulus materials consisted of the same text content (from the central tendency lesson) presented in four different screen density levels. The "conventional" frame consisted of definitions of mean, median, and mode (see Figure 2) presented on a single frame. When counting all letters and spaces contiguous with letters, the screen represented a density of 53%. This screen was then systematically divided into logical chunks to produce screens representing densities of 31%, 26%, and 22%. The text for 31% density required two screens, the 26% density required 3 screens, and the 22% density required 4 screens. It should be noted that the inclusion of additional screens to maintain equivalent content across variations presents a contrast with typical methodologies in which individual screens (an thus, varied amounts of total content) are judged. A paired-comparison design (Nunnally, 1967)

was employed involving a total of 6 comparisons presented in random order on an Apple //e monochrome screen.

Insert Figure 2 about here

The data were scaled using the procedures described by Thurstone (1927). Results as shown in Figure 3, indicated that the 31% density level was preferred over the other 3 density levels ($p < .10$). Interestingly, these results suggest that subjects prefer to read two screens of information (31% density level) as opposed to 1 screen with the 53% density level. Similarly, subjects may have felt there was too little information on the 26% (3 screens) and 22% (4 screens) density screens for the effort of paging through the information. The 31% density level may provide an optimum density level which allows the designer to make effective use of both horizontal and vertical typography to organize the material into a pleasing screen.

Insert Figure 3 about here

Discussion

In this closing section of the paper we will discuss implications of our studies of screen and text density in CBI. The three areas addressed are screen design, learner control, and adaptive design strategies.

Screen Design

The CBI screen presents the designer with a format that imposes several limitations not found in printed text, yet it offers several new possibilities for the display of instructional information. Specifically, computer screens offer alternatives for gaining and redirecting attention, and cueing (flashing, inverse type, animation, and sound). Computer displays are dynamic in that a designer can build a screen in segments to emulate the content's structure, or reconstruct only parts of a screen for comparisons. The unique limitation of the CBI frame is the amount of information that can be displayed with a 40 or 80 column by 24 row grid. Following a traditional page format for CBI frames results in either very dense displays or inordinately long lessons. Such designs have prompted Tullis (1981) and Kerr (1986) to suggest research is needed to determine the appropriate amount of text density for screen displays.

Our research on low-density text suggests that this format is a viable alternative to the standard text format used in printed materials. A frame designed with low-density text can incorporate white space, double-spacing, and headings adequately in a single frame. This leaner screen provides the designer with the space needed to organize text which increases its visual appeal (Grabinger, 1985), while minimizing the total number of screens required to present the same content, another attractive feature (see Study III). Ample use of white

space, and vertical and horizontal typography with low-density text will typically produce a unit of instruction that is comparable in frame length to the high-density text, but with approximately 50% fewer words. Our research found the low-density text was read faster and perceived as more sufficient than the same text presented in a print format.

Learner Control

Research on learner control (e.g., Tennyson, 1980; Ross & Rakow, 1981; 1982; Hannafin, 1984) has previously employed learner selections of the amount or difficulty of instructional support needed to achieve objectives. Learners were frequently found to make both inefficient and inappropriate choices, with high achievers selecting too much support and low-achievers too little. In contrast, text density simply manipulates the context of the lesson information as opposed to the number of examples or elaborations presented. Thus, it comprises a "stylistic" property of the lesson which LC subjects could vary based on preferences and reading skills, without necessarily having high abilities in or previous experience with the subject being taught.

Our research on learner control using text density as the decision variable, found the learner control groups learned better than groups receiving standard materials. The results indicated that the less skilled readers typically selected high-density text while the skilled reader selected low-density text. Implications from these results with information that that subjects varied their selections across units suggests that text density and other contextual variables can be used as an effective learner control variable in CBI (see also Ross, 1983).

Text Density as an Adaptive Strategy

Future research should further investigate the use of text density as a learner-control variable versus the use of program control or advisement. Such research holds the potential for developing prescriptions for text density based on levels of prior achievement and reading ability to provide for more efficient instruction. For example, initial text density levels could be established on the basis of a pretask measures so as to match the density level with the learner's characteristics. Text density could also be adapted online using procedures similar to those described by Tennyson (1984) in the MAIS. Again, the initial text density level could be established on the basis of prior experience or reading ability. During the lesson, the management system would monitor performance and time-on-task, and use the data to make appropriate changes in density level throughout the lesson. If a student were taking longer than the established mean, the management program might switch to low-density to improve the student's efficiency. Other research might investigate the use of high-density text during the initial stages of the lesson and then the gradual transition to low-density text as learner performance improves.

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The median corresponds to the middle frequency score in a ranked set of data

Half the scores will be higher
Half will be lower

X	f
Hi	50%
Median----------	
Lo	50%

If N=40 (40 scores), median = 20th score
If N=17, median = 8.5 highest score

Median corresponds to the 50th percentile

Higher than half the scores
Lower than half

The median, another measure of central tendency, is the number that corresponds to the middle frequency (that is, the middle score) in a ranked set of data. The median is the value that divides your distribution in half; half of the scores will be higher than the median, and half will be lower than the median.

X	f
Hi	50%
Median----------	
Lo	50%

It is important to remember that the median is the halfway point in the distribution--in terms of frequencies. For example, if N=40 (meaning that you have 40 scores), the median will be your 20th score (in terms of rank); if N=17, the median will be your 8.5 highest score, etc.

Another way of defining the median is to say that it corresponds to the 50th percentile.

In any distribution, the median will always be the score that corresponds to a percentile rank of 50; it is higher than half the scores, and lower than half the scores.

Figure 1. Sample text density screens.

Figure 2. Sample screen density.

Design #1

Whenever possible, it is always desirable to report all three measures of central tendency. They provide different kinds of information.

The MEAN is the score point at which the distribution balances.
The MEDIAN is the score point that divides the distribution in half.
The MODE is the highest frequency score.

In general, however, the mean provides the most useful measure of central tendency by taking into account the the value of every score

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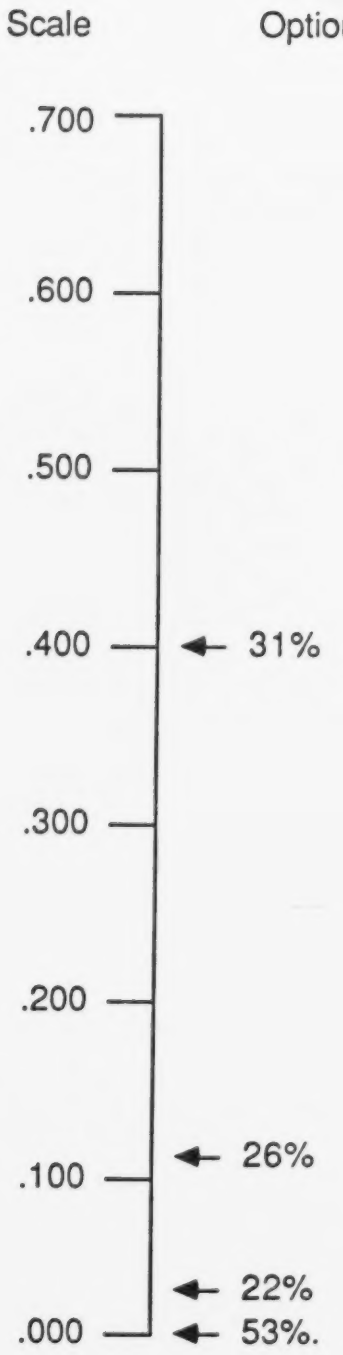

Figure 3. Scale of screen density preference